

amounts of hydrogen relative to mass flow rate upon deposition of material carried by a respective constituent of the precursor material. This basic principle underlying the invention and shown to be counter-intuitive on page 11 has now been recited in all independent claims and has substantially verbatim support on page 11, lines 4 - 20 of the specification as originally filed while it is clearly not limited to only two precursor gases. It is respectfully submitted that this support for the added claim recitation is the true measure of the scope of enablement of the disclosure rather than the two exemplary precursor gases in regard to which the invention has been explained. That is, the disclosure enables the exploitation of distinctive differences in evolution of hydrogen relative to mass flow rate of precursor material constituents to precisely monitor the deposition process, including the temperature thereof, at the deposition surface and can be performed successfully in accordance with the disclosure for any combination of materials for which distinctive amounts of hydrogen evolution relative to mass flow can be observed. Therefore, it is respectfully submitted that this ground of rejection is in error and, especially, moot in view of the amendments to claims 1 and 11 made above. Accordingly, it is respectfully requested that this ground of rejection be reconsidered and withdrawn.

Claims 1, 3 - 11 and 13 - 20 have been rejected under 35 U.S.C. §112, second paragraph: the Examiner indicating that the claims are indefinite because they do not indicate when to use certain regions of Figure 4 referred to in the claim and further commenting that Figure 4 illustrates a complete process and particular regions thereof may not be omitted. This rejection is respectfully traversed, particularly as being moot in view of the amendments made above.

Initially, it is respectfully submitted that there

is no requirement that the claims *explain* the invention but only define the invention in a manner distinct from the prior art and such that the scope of the claimed subject matter can be reasonably determined.

Therefore, recitation of when to process a semiconductor wafer in accordance with any particular operational processing region of Figure 4 as well as whether or not all operational process regions are included is completely irrelevant to the question of definiteness *vel non* of any claim. In fact, the processing regions which may be employed are entirely determined by the structure to be formed whether that structure is, for example, a homogeneous semiconductor film of a particular thickness or an alloy film having a particular profile of alloying material concentration. Further, in the former case where the film comprises only a single material, regions III, IV and V of Figure 4 which correspond to the introduction of an alloying material precursor gas would not be used and the Examiner's observation concerning a requirement that none of the regions of Figure 4 can be omitted is clearly untrue. In this regard, as disclosed, region VII does not correspond to material deposition while region I would not ordinarily be used since the temperature is not constant and both are included in Figure 4 only for illustrative purposes.

In any event, it is respectfully submitted that this rejection is based entirely on the reference to Figure 4 in claims 1 and 11 which has been clearly misunderstood (as, it appears, Figure 4 has been misunderstood, as well) and, while it is also respectfully submitted that this ground of rejection is clearly in error and improper, it has also been rendered moot by the removal of the reference to Figure 4. Therefore, it is respectfully requested that this ground of rejection be reconsidered and withdrawn.

Claims 1, 3, 4, 6 - 8, 11, 13, 14 and 16 - 18 have

been rejected under 35 U.S.C. §103 as being unpatentable over Nishizawa et al. in view of Maley et al. (abstract only) and Abelson et al. (abstract only) and claims 5, 9, 10, 15, 19 and 20 have been rejected under 35 U.S.C. §103 based on the same combination of references in view of the further teachings of Dubbelday et al. These grounds of rejection are respectfully traversed, particularly since the Examiner has not made a *prima facie* demonstration of obviousness of any claim and, further, the references relied upon not only fail to answer the subject matter of the claims but teach little, if anything of relevance to the invention beyond the admitted prior art.

Specifically, pages 2 - 4 of the specification discuss optical monitoring of film deposition processes and the inadequacies thereof for measurement of film thickness or alloy composition proportions and their inapplicability to monitor temperature accurately while the process and possibly the monitoring technique are sensitive thereto. Further, on page 4, it is noted that a residual gas analyzer has been used for monitoring deposition of GaAs films by detection of the reaction product methane but that such a process does not present the problems of monitoring the profile of proportionate composition of an alloy and that the monitoring provided is indirect and only qualitative.

Nishizawa et al. is principally directed to the monitoring of formation of crystals, particularly of compound materials such as GaAs and is only incidentally indicated as being applicable to silicon (column 9, line 37) thorough monitoring the precursor materials reaction by-products including methane (see column 7, lines 29 - 34) and thus has been established, by the present specification, to be substantially irrelevant, if not non-analogous to the present invention. No teaching or suggestion is seen of monitoring hydrogen partial pressure to monitor reactions at the deposition

surface, as the Examiner admits, which is the principal indicator of the deposition reaction in accordance with the present invention, as claimed, particularly as amended above.

The Maley et al. abstract mentions use of IR reflectance spectroscopy to monitor Si-H bonding in very thin films during reactive DC magnetron sputtering and "systematic variations with film thickness and hydrogen partial pressure during deposition" in regard to a "Si-H stretching mode" but does not appear to teach or suggest monitoring of hydrogen partial pressure, much less control of the deposition process in accordance therewith, much less any exploitation of differences in hydrogen evolution to quantitatively monitor the deposition process. On the contrary, the presentation of a "simple model...to explain the observed results", presumably of the bond stretching mode tends to indicate that the deposition process itself is neither monitored nor controlled through observation of distinctive amounts of evolved hydrogen which results in the hydrogen partial pressure. Neither alloy composition profile or temperature variation detection is mentioned based on hydrogen partial pressure. Therefore, Maley et al. does not supplement the teachings of Nishizawa et al. in regard to any salient aspect of the invention, as recited in the claims.

Similarly, the Abelson et al. (abstract) indicates that a study of hydrogen release during growth of *hydrogenated amorphous* silicon which, as disclosed therein and in the present specification (see page 10; contrasting growth on a polycrystalline surface with the growth of a film on a crystalline surface) is a much different mechanism and much less quantitatively deterministic than growth on a monocrystalline surface. That is, Abelson et al. indicates that hydrogen is released "whenever the hydrogen fraction in the growth

flux exceeds the hydrogen incorporation rate into the film" that is evidently somewhat dependent on prevailing hydrogen partial pressure whereas, while a silicon crystal lattice will have a hydrogen monolayer, no significant hydrogen is incorporated into the film; allowing the monitoring of hydrogen in accordance with the invention to be quantitatively representative of the reaction at the deposition surface in accordance with the invention. In other words, it appears that the hydrogen partial pressure in Abelson et al. has an effect on resulting hydrogen incorporation into a film rather than the hydrogen partial pressure being a direct and quantitative indicator of the deposition reaction. Further, and contrary to the invention, Abelson et al. mentions (emphasis added) "variation of reacted hydrogen flux with hydrogen partial pressure" which would appear to preclude or be mutually exclusive of the quantitative evaluation of the deposition reaction in accordance with the invention. In summary, Abelson et al. is merely seen to confirm the deposition mechanism discussed in connection with Figure 1 of the present application and does not teach or suggest anything of relevance to the present invention or supplement the deficient teachings or suggestions of Nishizawa et al. and/or Maley et al.

In regard to Dubbelday et al. the Examiner further admits that the combination of Nishizawa et al., Maley et al. and Abelson et al. do not teach or suggest deposition of SiGe and relies on Dubbelday et al. to do so. However, Dubbelday et al. is only seen to regulate temperature to regulate relative Ge content and is not seen to provide any teaching or suggestion of monitoring of the Ge content, as deposited, particularly through monitoring of hydrogen partial pressure, given the effects of the presence of Ge on hydrogen evolution when deposited with Si. Therefore, Dubbelday et al. does not provide teachings or

suggestions that supplement the other applied references as to any salient feature of the present invention, as claimed.

In essence, The Examiner has first relied on Nishizawa et al. which teaches virtually nothing of relevance to the invention and which is substantially non-analogous to the invention while admitting that Nishizawa et al. does not teach or suggest monitoring of hydrogen partial pressure which is a principal feature of the method and apparatus claimed and seeks to supplement Nishizawa et al. with Maley et al. and Abelson et al. based on a mere mention of hydrogen partial pressure therein but which otherwise teach substantially away from the present invention and teach or suggest little, if anything, of relevance to the invention beyond the admitted prior art. The Examiner then seeks to extend the teachings of the references to SiGe with Dubbelday et al. even though the Examiner has not addressed basic features of the invention in exploiting distinctive hydrogen evolution as a direct indicator of a deposition reaction. Such an application of the prior art falls far short of making a *prima facie* demonstration of obviousness of any claim in the application and clearly is grounded in hindsight, as well.

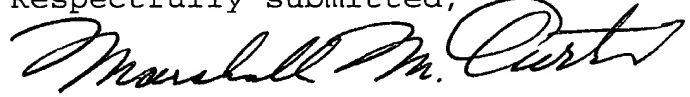
Accordingly, it is respectfully submitted that the stated grounds of rejection based on prior art are clearly erroneous and improper. Therefore, reconsideration and withdrawal of the same is respectfully requested.

Since all rejections, objections and requirements contained in the outstanding official action have been fully answered and shown to be in error and/or inapplicable to the present claims, it is respectfully submitted that reconsideration is now in order under the provisions of 37 C.F.R. §1.111(b) and such reconsideration is respectfully requested. Upon

reconsideration, it is also respectfully submitted that this application is in condition for allowance and such action is therefore respectfully requested.

If an extension of time is required for this response to be considered as being timely filed, a conditional petition is hereby made for such extension of time. Please charge any deficiencies in fees and credit any overpayment of fees to Deposit Account No. 09-0458 of International Business Machines Corporation (E. Fishkill).

Respectfully submitted,



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## APPENDIX

Page 16, line 19+:

Thus, if during the calibration period, the germane mass flow rate can be accurately known, the percentage of germanium being deposited in a SiGe film in the actual (e.g. production) process sequence can be known from the rate of hydrogen evolution at any given point in time during the deposition process for any given temperature. In other words, calibration relating hydrogen partial pressure to germane gas flow rates allows conversion of hydrogen partial pressure variation with time to germane flow rate variation with time and, in turn, SiGe alloy film thickness and percentage germanium in the SiGe alloy at any given point in time [as] is a direct function of hydrogen partial pressure. It should also be appreciated from Figure 5 that hydrogen evolution is especially sensitive to the concentration of germanium at the deposition surface and thus to the amount of germanium incorporated in the SiGe alloy film.

Page 17, line 20+:

As a practical matter, the calibration can potentially be complicated by several factors. For example, some hydrogen evolution will be due to deposition of silicon or SiGe alloy on polycrystalline silicon which may be present on the interior of the reactor vessel in which the deposition is performed. However, as noted above, film deposition on polysilicon [proceed] proceeds much more slowly than deposition on monocrystalline silicon and the hydrogen evolution due to deposition on polysilicon will generally be manifested as a low level background partial pressure which will be specific to the reactor vessel. Therefore, calibration as described above which is directed to variation in hydrogen partial pressure with



variation in other process parameters is generally sufficient to avoid causing significant errors in germanium percentage or temperature determination and silicon film thickness.

Claims 1 and 11:

1. (Thrice amended) A method of depositing a film containing silicon on a crystalline silicon surface, said method including steps of

introducing a gas containing precursor material into a reaction vessel, a constituent material of said precursor material producing evolution of a distinctive amount of hydrogen relative to mass flow rate upon deposition alone or in combination with another constituent material of said precursor material,

adsorbing an activated species formed from said precursor material on said crystalline silicon surface, and

determining a partial pressure of hydrogen in residual gases as said activated species is deposited on said crystalline silicon surface,

controlling in real time at least one of temperature and mass flow of said precursor material in said reactor vessel in response to said partial pressure of hydrogen[, wherein said step of controlling includes controlling in real time at least one of temperature and mass flow according substantially to the temperature profile and gas flow profile depicted in regions I, II, IV and VI of Figure 4].

11. (Thrice Amended) Apparatus for depositing a film containing silicon on a crystalline silicon surface including

means for introducing a gas containing precursor material into a reaction vessel such that an activated species formed from said precursor material is adsorbed on said crystalline silicon surface, a constituent

material of said precursor material producing evolution of a distinctive amount of hydrogen relative to mass flow rate upon deposition alone or in combination with another constituent material of said precursor material, and

means for determining a partial pressure of hydrogen in residual gases as said activated species is deposited on said crystalline silicon surface,

means for controlling in real time at least one of temperature and mass flow of said precursor material in said reactor vessel in response to said partial pressure of hydrogen[, wherein said means for controlling includes means for controlling in real time at least one of temperature and mass flow according to the temperature profile and gas flow profile depicted in regions I, II, IV and VI of Figure 4].